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THE DETERIORATION OF FELLED WESTERN YELLOW PINE ON INSECT-CONTROL PROJECTS.[1]

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CONTENTS.

INTRODUCTION.

During the past 15 years extensive insect-control measures have become necessary in various localities in the western United States in order to check epidemics of the western pine beetle (*Dendroctonus brevicomis* Lec.) and the mountain-pine beetle (*Dendroctonus monticolae* Hopk.) on western yellow pine (*Pinus ponderosa* Laws.), lodgepole pine (*Pinus contorta* Loud.), western white pine (*Pinus monticola* Dougl.), and sugar pine (*Pinus lambertiana* Dougl.). Briefly, control consists in felling and barking the infested trees (or burning the bark in the case of *Dendroctonus brevicomis*), in order to destroy the overwintering stages of the beetles. The trees usually are limbed well into the top but are not cut into log lengths.

The attacks of the western pine beetle on western yellow pine have been widespread, and consequently the most extensive control projects have been concentrated on this tree species. At present control work is under way in the yellow-pine regions of British Columbia and central California, while a large project was begun in the spring of 1922 in the Klamath Lake region of southern Oregon.

The southern Oregon–northern California project begun in the spring of 1922 necessitated the felling of about 16,000 merchantable western yellow pines, with an occasional sugar pine, comprising ap-

[1] This study was made in cooperation with the Klamath Forest Protective Association at Klamath Falls, Oreg. Without the yearly records of the association giving the location of felled trees, the study would have been impossible. The writer is indebted to J. F. Kimball, secretary-treasurer, and to H. H. Ogle, of the same association, for valuable assistance in obtaining the field data.

proximately 16,000,000 feet board measure, over an area roughly of 200,000 acres. Further work in the next three or four years will probably involve cutting an additional 20,000,000 feet of merchantable timber on adjoining areas. These trees must be left on the ground until such time as they can be reached by logging operations. The rate of deterioration of this felled timber then becomes of paramount importance. It is in connection with this project that the study reported here was made.

METHOD OF COLLECTING DATA.

Local control work has been carried on in this region for some years by the Klamath Forest Protective Association, and records of this association were available, giving the general location of trees felled yearly since 1915. From these records, felled trees were relocated and examined during November, 1921.

Each tree was opened up sufficiently with ax and saw to permit scaling in 16-foot logs with the Scribner decimal C scale, according to standard commercial practice. Logs two-thirds or more unmerchantable by volume were culled. Diameter measurements were taken to the nearest inch, and length measurements to the nearest tenth of a foot. The gross scale where given is the actual merchantable volume in the trees at the time of felling, determined when this study was made. In making the measurements of decay, the subsequent advance of decay present in the living tree at the time of felling was disregarded. In the region in which the trees were studied the decays in living yellow pine seem to advance very slowly or not at all after an infected tree is felled. Characteristically, western yellow pine is a sound species, and the normal loss through decay in stands of living trees does not exceed 2.5 per cent and may be much less. The only two kinds of decay found in the trees examined which were there at the time of felling were rots caused by the ring-scale fungus (*Trametes pini* (Thore) Fr.) and brown cubical butt-rot caused by the velvet-top fungus (*Polyporus schweinitzii* Fr.). Two trees had been infected with the first-named rot, with a slight loss resulting. Brown cubical butt-rot had also been present in two trees, but there was little indication left of the decayed wood, which had been almost completely destroyed by fire when the bark removed from the trees was burned.

Data were obtained on a total of 100 trees, all western yellow pine, near Bly, Klamath Falls, and Keno, in Klamath County, Oreg., at elevations around 6,000 feet above sea level. The site conditions were essentially the same for all the localities. These trees varied from 16 inches to 43 inches in diameter outside bark at stump height, and the usual stump height ranged from 2½ to 3 feet.

RATE OF DETERIORATION.

These felled trees deteriorate with extreme rapidity, far more rapidly than the casual observer is led to believe. The heat from burning the bark and from the sun's rays results in a pronounced drying of the outer sapwood to depths averaging one-half inch. This outer layer, being too dry to decay, remains hard and sound for several years, and if tested superficially leads to the belief that

the tree is sound throughout, when as a matter of fact it may be commercially a complete loss through decay. Table 1 shows the rate of deterioration.

TABLE 1.—*Rate of deterioration of felled western yellow-pine trees in Klamath County, Oreg.*

When cut.	Seasons of exposure.	Volume (board feet).			Percentage of cull.	Trees with merchantable volume.		Average diameter inside bark stump (inches).	Number of trees (basis).
		Gross.	Cull.	Net.		Number.	Percentage of total.		
1	2	3	4	5	6	7	8	9	10
April, 1921	1	6,400	810	5,590	13	6	100	24	6
December, 1920	1	11,350	2,060	9,290	18	12	100	23	12
February, 1920	2	11,610	7,360	4,250	63	11	79	23	14
November, 1919	2	8,080	6,120	1,960	76	6	75	21	8
Spring of 1919	3	15,870	12,900	2,970	81	10	62	24	16
Spring of 1918	4	2,650	1,790	860	68	3	100	23	3
April, 1917	5	35,510	28,960	6,550	82	7	44	31	16
Spring of 1916	6	13,270	12,060	1,210	91	2	14	23	14
Spring of 1915	7	11,470	10,710	760	93	1	9	25	11

In Table 1 the expression "seasons of exposure" means the number of growing seasons that have elapsed since the trees were felled. It is, of course, during the growing season that the greatest deterioration occurs, although loss continues throughout the year. This is shown by the fact that the trees cut in April, 1921, and exposed for one season show a loss of 13 per cent, while those cut in December, 1920, also exposed for one season but with four additional months in winter and early spring, show a loss of 18 per cent. The same relation holds for the trees exposed for two seasons but cut at different times.

The important feature of Table 1 is the enormous increase in the cull percentage after the first season. This increase is from 13 and 18 per cent for the first season to 63 and 76 per cent for the second season and is so great that from an economic standpoint felled trees must be utilized before they pass into the second season of exposure. This means that the bulk of the trees cut on a control project must be regarded as a loss, since it is at present commercially impossible so to adjust logging operations that trees scattered over a large area can be picked up in a single season.

After the second season deterioration increases steadily, until by the end of the seventh season there is little merchantable volume to be obtained, and this only in an occasional tree much larger than the average or with some other abnormal condition. For example, the merchantable volume in the trees cut in 1916 came from two trees only, as is shown in column 7 of Table 1. One of these was a large tree with a diameter inside bark at stump height of 37 inches, while the other, though 11 inches smaller in the same dimension, had an unusually resinous butt log. The 760 feet board measure in the 1915 trees came from the first three logs in a 43-inch tree.

The criticism may be made that Table 1 is based on insufficient data. An examination of the table will show that the trees are well

distributed by seasons of exposure except in the case of those cut in 1918, of which there are only three, all that could be obtained. The basis for this class is insufficient. The cull percentage shows a steady increase and the percentage of total trees with merchantable volume a steady decrease except in the 1918 trees. This points to a sufficient basis for the other classes. Then, too, during the course of the field work the similarity in condition between trees exposed for the same number of seasons was quite apparent.

Figure 1, which is a diagrammatic smoothed curve based on Table 1, illustrates the rate of deterioration of the down timber.

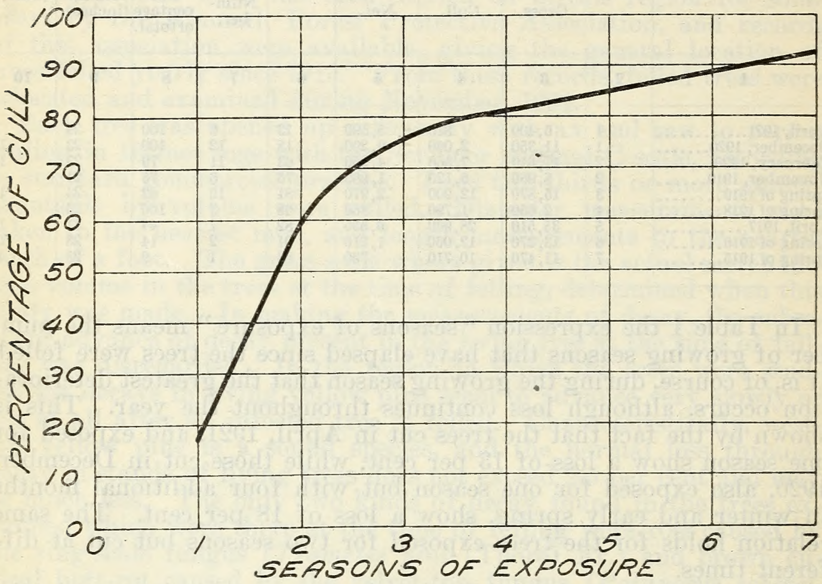

FIG. 1.—Diagrammatic smoothed curve, illustrating the rate of deterioration of felled western yellow pine.

CAUSES OF DETERIORATION.

In Table 1 sap-stain is not considered a defect. While this discoloration does degrade the lumber, discolored wood can still be used for a variety of purposes. In this region blue-stain caused by the fungus *Ceratostomella* sp. is most common, while a brown stain, of which the causal fungus is probably *Alternaria* sp.[2] is sometimes found. Staining is practically confined to the sapwood, rarely penetrating the heartwood. The extent of the stain in a tree is easily misjudged. As previously pointed out, there is a very dry outside layer of sapwood, too dry to stain, and a hasty examination may show bright wood, but deeper chopping will reveal the stain. By the end of the first season all the sapwood with the exception of the outer layer was heavily stained in the trees examined. In the upper portions of the trees, where the bark had been left on, this outer layer, since it had been kept moist, was also stained. The discoloration

[2] Hubert, Ernest E. Some wood stains and their causes. *In* Hardwood Rec., v. 52, no. 11, p. 17–19, illus. 1922.

first began along the checks and then spread over the entire sapwood. If stained sapwood is considered a defect the loss for Table 1 after one season of exposure would amount to 78 per cent in the trees cut in April, 1921, and 67 per cent in the trees felled in December, 1920. This difference may be mere chance or it may indicate that the winter-felled trees for some unknown reason were less susceptible to discoloration by the time that climatic conditions in spring or summer favorable for staining arrived. Observations made on windthrown yellow pine in this region showed that heavy staining began in July. To avoid sap-stain as much as possible trees should be logged before that time.

That the principal causes of deterioration were relatively few and well defined is shown in Table 2.

The most important cause of cull in the trees exposed for one season was checks. Checks were confined mostly to the sapwood but in some cases extended deep into the heartwood.

TABLE 2.—*Causes of deterioration of felled yellow-pine trees in Klamath County, Oreg.*

When cut.	Seasons of exposure.	Cull (percentage of gross volume.)					
		Checks.	Sap-rot.	Heart-rot.	Broken in felling.	Burned.	Borers.
1	2	3	4	5	6	7	8
April, 1921	1	13.7	...	...	...	...	...
December, 1920	1	16.2	1.5	...	0.2	0.3	...
February, 1920	2	16.9	24.6	...	...	21.9	...
November, 1919	2	11.5	57.3	...	3.7	3.2	...
Spring of 1919	3	...	59.4	9.6	1.2	11.1	...
Spring of 1918	4	...	63.4	4.2	...	...	...
April, 1917	5	1.4	53.2	15.0	.5	9.6	1.9
Spring of 1916	6	3.9	63.7	14.1	.8	8.3	...
Spring of 1915	7	.3	57.0	30.3	...	5.8	...

Checking usually began and was most severe on the side of the trunk exposed to the direct rays of the sun. Exceptions to this rule were found where particularly intense heat had caused severe checking when the bark was burned. Normally the loss through checking in any one tree resulted from several or numerous checks, but in a very spiral grained tree a single deep check twisting around the tree sometimes caused all the loss. Considering column 3 of Table 2 it would seem that the loss through checking decreases with the length of exposure after the second season, while it is self-evident that this loss should increase slightly or remain about the same. The explanation is that as sap-rot becomes more severe the checks become obscure or disappear completely, and in scaling the loss from this source is then difficult to separate from that caused by sap-rot.

There was little sap-rot during the first season. In fact, the entire 170 board feet given in Table 2 were obtained from a single tree. But by the end of the second season the loss from this cause was heavy and continued so. After that time sap-rot was the most important factor in deterioration. In poles and young thrifty standards with wide sapwood, sap-rot by amounting to two-thirds or more of the gross volume often caused the loss of the entire tree. It fol-

lowed then that poles and young thrifty standards were subject to much more rapid deterioration than large trees, in which the ratio of sapwood to heartwood is inverted.

The upper side of the trunk decayed most rapidly, and the under side, the portion resting on the ground, much more slowly. This is probably explained by the retarding effect on the development of wood-destroying fungi from the excessive moisture content, lessened oxygen supply, and lower temperature of the wood of the under side as compared with the upper side. Decay first appeared along the checks, but avoided the dried outer layer of sapwood. Tongues of decay extended down from the ends of the checks. The decay then spread from the checks, finally involving the entire sapwood with the exception of the outer layer. Where the bark was left on in the top, the outer layer also decayed. Barking the tree somewhat retards decay, but not enough to be of practical importance, while on the other hand it promotes checking.

Generally it was impossible to determine the exact kind of decay in the different trees, but where this was done it was found that a white cellulose pocket rot [3] caused by *Polyporus anceps* Pk. was most common, while a brown friable rot caused by the brown Lenzites (*Lenzites sepiaria* (Wulf.) Fr.) and a yellow-brown friable rot caused by *Fomes pinicola* (Fr.) Cke. occasionally occurred.

Heart-rot was not found in the trees until the third season of exposure. Decay first appeared as tongues running in from the sapwood or following in along deep checks. The white cellulose pocket rot was most common.

A negligible amount of loss resulted from breaks, usually in the top, when the trees were felled.

A more important source of cull was fire at the time the trees were felled and bucked. This sometimes did considerable damage. When the bark was burned, trees with open wounds were very likely to burn out along the scar and for some distance in advance. Fire scars, particularly in pitchy butts, were common starting points for destructive burns. Felling trees across one another or leaving limbs resting on the trunk resulted in additional loss from fire.

The loss caused by wood-boring insects was negligible. Ambrosia beetles did not attack the trunk from which the bark had been removed, while the round-headed and flat-headed borers did not attack the trees until sap-rot was well started.

From the foregoing discussion of Table 2 it is apparent that while checks caused some loss (and in a lesser degree so did fire), decay, particularly the very rapid decay of the sapwood, is responsible for most of the deterioration in these trees.

CONCLUSIONS.

The facts brought out in this bulletin should not be considered as of value for local application only. The climatic conditions of the Klamath Lake region, characterized by a small yearly precipitation, with a long summer drought, often beginning in the late spring and extending well into the fall, and low winter temperatures, are

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[3] This decay has also been called western red-rot. According to Dr. J. R. Weir, *Polyporus ellisianus* Murr. as known in the West is the same as *P. anceps* Pk.

exactly similar to those of a great part of the yellow-pine belt of eastern California, Oregon, and Washington, and not markedly at variance with conditions in other western yellow-pine regions in North America.

These results should prove generally applicable, with minor variations, on control projects in western yellow pine. Timber averaging smaller than that studied here will deteriorate more rapidly, while the deterioration in larger timber will, of course, be slower.

The felled and barked trees were completely sap-stained by the end of the first season of exposure. If sap-stain is considered a defect serious enough to make discolored wood worthless for lumber, there is such a large loss the first season that utilization by midsummer is imperative. However, as a rule, stained lumber is only degraded and not culled.

Deterioration is very rapid and is chiefly caused by decay, particularly the very rapid decay of the sapwood, followed more slowly by the breaking down of the heartwood. The resulting loss is so high by the end of the second season that felled trees must be utilized by the beginning of the second season, or else the volume of merchantable wood obtained is so small as to be of little commercial importance. Consequently, the timber in most of the trees cut on a control project becomes a complete loss, since under present economic conditions it is usually not possible to utilize scattered trees over a large area within such a limited period of time.

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